Malnutrition in infants aged 6-23 months in China's poorest rural counties from 2016 to 2021: cross sectional study

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ABSTRACT

OBJECTIVES

To assess trends and differences in child malnutrition by population subgroups among infants aged 6-23 months in China's poorest rural counties.

DESIGN

Six consecutive cross sectional surveys were conducted annually.

SETTING

The study was conducted in 116 counties in 19 provinces from 2016 to 2021, representing China's 832 poorest counties.

PARTICIPANTS

A total of 210 088 participants were selected through a multistage cluster sampling procedure; all participants were infants aged 6-23 months.

MAIN OUTCOME MEASURES

Prevalence of anaemia, stunting, wasting, overweight, and growth status in children (measured by length-for-age and weight-for-length z scores).

RESULTS

Four main malnutrition forms were prevalent in 2016: anaemia (prevalence 18.3%), stunting (7.5%), wasting (4.7%), and overweight (3.1%). The prevalence of any two coexisting malnutrition forms was low. All four forms of malnutrition decreased from 2016 to 2021. Anaemia decreased by more than half, with an annual reduction rate of 9.11% (95% confidence interval (CI) 4.83% to 13.20%). Stunting was reduced by over a third, with an annual reduction rate of 10.44% (7.56% to 13.22%), which is faster than the World Health Organization's target of 3.9%. Differences in child growth by county gross domestic product quarters were small and decreased over time, but growth differences related to education persisted. Infants whose mothers completed education up to primary school level had approximately twice the risk of stunting (adjusted rate ratio 2.29 (95% CI 1.87 to 2.81)) and wasting (1.73 (1.40 to 2.13)) compared with children whose mothers had an education level of a college degree or above. Boys had poorer growth and higher anaemia than did girls. For all outcomes, differences related to sex and education were greatest at 6 months of age.

CONCLUSIONS

Education related inequalities in growth of infants persists, with these differences particularly affecting children whose mothers completed education only up to primary school level.

WHAT IS ALREADY KNOWN ON THIS TOPIC

Sustainable development goal 2.2 involves ending all forms of malnutrition by 2030, prioritising the first 1000 days of a child's life

Prior studies of child malnutrition from China have focused on school aged children and adolescents, little is known about children under the age of 5

The Chinese government has given poverty alleviation top priority, although data on child nutrition are lacking from the poorest populations, particularly for those disaggregated by small geographical areas and subpopulation groups

WHAT THIS STUDY ADDS

China is making progress in eliminating all forms of child malnutrition in its most susceptible populations

Differences by county GDP decreased over time, but inequalities related to education remained

All outcomes showed differences at 6 months of age, suggesting that the optimal time for intervention is during the breastfeeding period and even earlier

Introduction

Malnutrition accounts for almost half of the deaths of children younger than 5 years globally.[1] In 2012, the World Health Assembly established three relevant targets to achieve by 2025: reduce stunting in children under 5 by 40%; reduce childhood wasting to less than 5%; and ensure that prevalence of childhood overweight does not increase.[2] Sustainable development goal 2.2, one of 17 goals, aims to end all forms of malnutrition by 2030. A consensus was reached to prioritise interventions during the first crucial 1000 days of a child's life—from conception to the age of 2 years.[3 4] Disaggregated data by geographical areas and subpopulation groups are essential to support subnational efforts and address inequities.[5 6]

China has made progress in reducing child undernutrition. A 2014 study assessing trends of growth among children and adolescents from 1975 to 2010 (covering a 35 year period) reported decreasing levels of underweight and stunting.[7] Much of this success can be attributed to rapid economic development and reduced urban-rural disparities; however, these events have been accompanied by an increase in obesity.[8-10] Moreover, previous analyses have focused only on the height and body mass index of school aged children and adolescents. Data for children under the age of 5 years and on specific sustainable development goal indicators are lacking. Additionally, little is known about differences in child malnutrition between small geographical areas and subpopulations.

In 2013, China prioritised poverty alleviation by targeting its 832 poorest rural counties, with government investment reaching USD $246 billion (€219 billion, £184 billion) by 2021 (supplementary S1).[11-13] A broad programme was adopted to promote health equity and alleviate poverty by enhancing

compulsory education, ensuring safe housing and basic healthcare, guaranteeing safe drinking water and sanitation, and improving child nutrition. Importantly, the government augmented the national fortified complementary food supplement programme, or Ying Yang Bao. This programme distributed complementary soy based food supplements, rich in macronutrients and micronutrients, to all children aged 6-23 months living in these counties. However, despite these efforts, limited research exists on China's progress in addressing child malnutrition in rural poor populations.[7-10]

This study focuses on analysing trends in stunting, wasting, overweight, and anaemia among children aged 6-23 months in China's poorest rural populations. By incorporating socioeconomic factors and children's age in months, we aimed to identify the underlying factors contributing to disparities in health outcomes in rural contexts.

Methods

Study design and data sources

This study used six rounds of cross sectional survey data collected annually from 2016 to 2021 from the monitoring and evaluation project of the national fortified complementary food supplementation programme of China in poverty stricken counties (ie, the Ying Yang Bao programme). For all surveys, a four stage cluster sampling procedure was used to select participants. In the first stage, all 832 poverty stricken counties were stratified into each of the 19 provinces and ranked by GDP and population size; then, seven counties were randomly selected from each province (for one province where only five counties were in poverty, all were selected). All following surveys used the same counties that were sampled in 2016. During these surveys, some provinces expanded their sample size, and eight counties from the original sampling were not followed up because of uncontrolled factors such as natural disasters. In the second stage, townships within each county were ranked by per capita net income and population size, with five townships randomly selected from each county. In the third stage, three to five villages were randomly selected from each township. Finally, 12-20 children aged 6-23 months were randomly selected from each village. Considering the baseline stunting prevalence of 10% and an expected reduction proportion of 20%, a minimum of 300 children per township and 2100 per province were predetermined.

For each county, doctors from the county maternal and child health hospital were recruited for the programme. Four doctors were responsible for growth monitoring, five to eight conducted the interviews, and one managed on-site quality control. After two days of training, county doctors travelled to the selected townships to conduct the survey from July to August. Village doctors notified and escorted the selected children and their caregivers to the township hospital where the four trained doctors conducted anthropometric measurements and collected finger blood samples. All procedures, including training, were standardised by a predefined protocol (supplementary text S2). Face-to-face interviews were then held with the children's caregivers to collect basic information about the children and their feeding habits, and parents, using a 24 h recall form (supplementary text S3). All participants were required to sign an informed consent form (supplementary text S4). The non-response rate was less than 2%. Overall, 73.9% (189 617 out of 256 505) of the respondents were mothers, 21.4% (54 906 of 256 505) were grandparents, 4.1% (10 569 of 256 505) were fathers, and 0.5% (1413 of 256 505) did not provide this information. All completed forms underwent a final on-site review by the head of the county maternal and child health hospital for logical inconsistencies and missing items. The Chinese Centre for Disease Control and Prevention managed this survey.

Definition of outcomes and adjustments variables

The outcomes of interest were stunting, wasting, overweight, and anaemia. Length-for-age z scores and weight-for-length z scores were analysed with the World Health Organization's (WHO's) Anthro software (version 3.2.2); a length-for-age z scores of less than −2 was defined as stunting, a weight-for-length z scores of less than −2 was defined as wasting, and a weight-for-length z scores more than 2 was defined as overweight. WHO adjusted their 2024 criteria of haemoglobin concentration for altitude to sea level, and anaemia was defined as a haemoglobin concentration below 105 g/L.[14] Children were classified into quarters according to county annual GDP, adjusting the monetary values of per capita GDP to those of 2016. This approach showed the change in the proportion of children according to the counties' economic development. Mothers' education levels were determined through survey questions. These levels were classified into four groups: up to primary education (6-12 years old), middle school (13-15 years), high school (15-17 years), and college or above (18 years and older). Additionally, the mothers' ethnic group and the child's sex, age in months, health status, and feeding habits (obtained from the questionnaire) were included as covariates. The self-reported incidences of diarrhoea and acute respiratory infection in the preceding two weeks were used to determine the children's health status. Age was divided into three equal groups. Feeding habits included whether the child was breastfed and whether they had followed the recommended minimum acceptable diet recommended by WHO.[15]

Statistical analysis

Yearly trends for each form of malnutrition and all possible comorbidities were described. To explore the importance of double burdens, comorbidities were first excluded from each single form (ie, not counting stunting and overweight in stunting), and then comorbidities were included (ie, double counted) in each single form to compare the trends and prevalence. Once done, Varghese and Stein's approach

were adopted to test whether two malnutrition forms coincided non-randomly.[16]

The prevalence of the four individual malnutrition forms and the concentration of haemoglobin were described by age (in months) to explore the trajectory of child nutrition by sex and socioeconomic status, using cubic or quadratic splines to fit the age patterns.[17] Socioeconomic inequalities were visualised by determining annual trends in prevalence stratified by four GDP groups and the mother's education level.

Multilevel Poisson regression, which accounts for the sampling stratification and clustering at the county, township, and village level, was used to assess crude and adjusted rate ratios (RRs) of each malnutrition form over time and in various groups. Rate ratios were adjusted for years, GDP groups, the mothers' education level, and ethnic group, and for the children's sex, age in months, and health status and feeding habits. The year was modelled as a linear variable to estimate the average annual rate of reduction (1-rate ratios for the variable year).[18] Yearly trend interactions were explored with GDP quarters, mother's education, and children's sex and age in months to examine whether the prevalence changed at the same rate over time in different subgroups.

The SVY command in STATA was used to adjust the survey design. The data were weighed against the probability that a child would be selected, using the number of live births in 2016 to determine the population size. All missing values were excluded from the analysis.

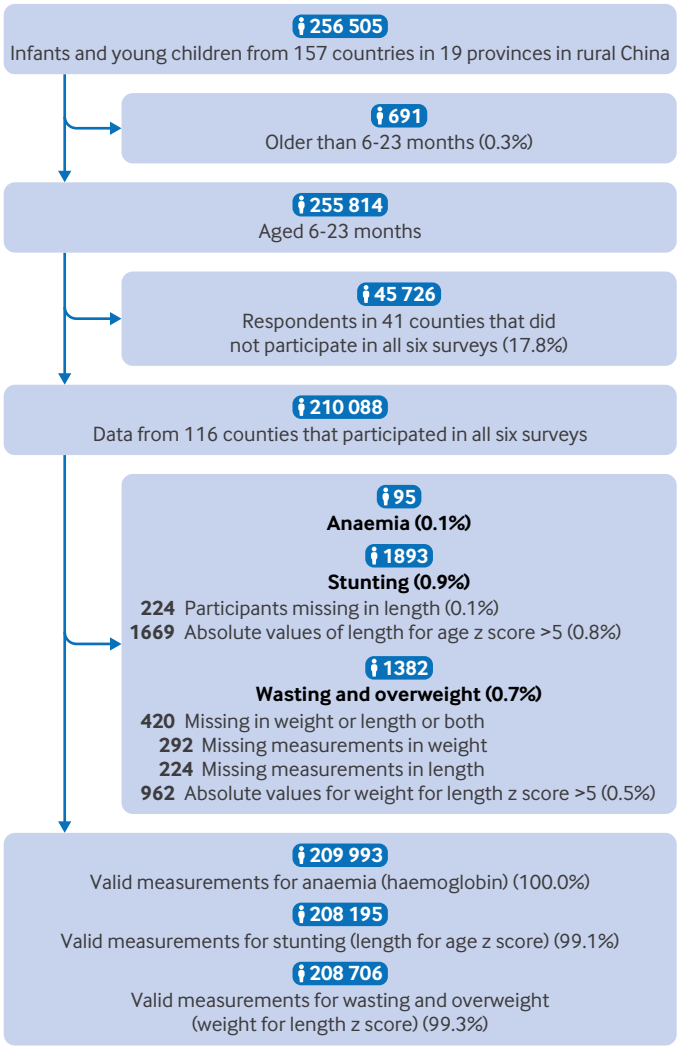

Fig 1 | Flowchart of the study population

Patient and public involvement

Despite distributing complementary food supplements, county level maternal and child health doctors provided health education and consultation services to the caregivers of participating children. Specific advice was given on breastfeeding and complementary feeding. The Ying Yang Bao programme was shared with the local government (health commission), and disseminated through newspapers, television broadcasts, radio, websites, and social media to raise public awareness. The public and caregivers supported the programme by providing input, especially for knowledge sharing and peer health education on breastfeeding and complementary feeding. They contributed to the design and production of multiple health education methods, including village broadcasts, posters, and slogans painted on village central squares, and online chat groups where caregivers shared their feeding experiences. Moreover, children's healthy appearance and positive feedback from caregivers on child health facilitated peer-to-peer sharing of health information and enhanced adherence to recommended practices.

Results

We included 210 088 children aged 6-23 months from 116 (74%) of 157 counties who had completed the six surveys (supplementary figure S1, and tables S1 and S2 for the sensitivity analysis for the 157 counties). Missing measurements were noted in 95 participants (0.1%) for haemoglobin, 224 (0.1%) for length, and 292 (0.1%) for weight. We excluded children with absolute values of z scores more than 5 for length for age (n=1669 (0.79%)) and for weight for length (n=962 (0.46%)). Of 210 088 children, valid measurements were 209 993 (100.0%) for anaemia (haemoglobin), 208 195 (99.1%) for stunting (length for age) and 208 706 (99.3%) for wasting or overweight (weight for age) (fig 1).

Table 1 shows the participants' main characteristics. Children were balanced in sex and age, and missing values were rare. Income had increased substantially: in 2016, 44.0% of children were in the poorest quarter (per capita GDP USD <$2352) and 11.6% of children were in the richest quarter (>$3909). In 2021, the proportion of children in the poorest quarter in the survey area had decreased to 10.9%, while that of the richest had increased to 43.2%. Mothers' education levels also improved. In 2016, 77.2% of the mothers had completed education up to the middle school level.

Table 1 | Characteristics of the mother-child pairs among children aged 6-23 months representing 832 poorest rural counties in China, 2016-21

Characteristics	2016 (n=34 977)	2017 (n=34 116)	2018 (n=35 373)	2019 (n=35 335)	2020 (n=35 262)	2021 (n=35 025)	Overall (n=210 088)
Socioeconomic characteristics							
County per capita GDP quarters:							
Richest (USD >$3909)	4064 (11.6)	7030 (20.6)	7096 (20.1)	7951 (22.5)	11 111 (31.5)	15 121 (43.2)	52 373 (24.9)
Richer ($3103-3909)	5434 (15.5)	5439 (16.0)	8019 (22.7)	11 838 (33.5)	12 136 (34.4)	9745 (27.8)	52 611 (25.0)
Poorer ($2352-3103)	10 079 (28.8)	10 660 (31.3)	9491 (26.8)	8295 (23.5)	7570 (21.5)	6333 (18.1)	52 428 (25.0)
Poorest (<$2352)	15 400 (44.0)	10 987 (32.2)	10 767 (30.4)	7251 (20.5)	4445 (12.6)	3826 (11.0)	52 676 (25.1)
Mother's education:							
College or above	2681 (7.7)	3679 (10.8)	4582 (13.0)	5385 (15.2)	5905 (16.8)	6453 (18.4)	28 685 (13.7)
High school	5058 (14.5)	5391 (15.8)	5930 (16.8)	6276 (17.8)	6528 (18.5)	6857 (19.6)	36 040 (17.2)
Middle school	20 668 (59.1)	19 317 (56.6)	19 344 (54.7)	18 599 (52.6)	18 265 (51.8)	17 248 (49.2)	113 441 (54.0)
Up to primary school	6328 (18.1)	5567 (16.3)	5479 (15.5)	5029 (14.2)	4515 (12.8)	4387 (12.5)	31 305 (14.9)
Missing	242 (0.7)	162 (0.5)	38 (0.1)	46 (0.1)	49 (0.1)	80 (0.2)	617 (0.3)
Mother's ethnic group:							
Han	26 491 (75.7)	24 856 (72.9)	25 336 (71.6)	25 684 (72.7)	25 264 (71.7)	24 855 (71.0)	152 486 (72.6)
Other ethnic groups	8262 (23.6)	9201 (27.0)	10 032 (28.4)	9651 (27.3)	9998 (28.4)	10 170 (29.0)	57 314 (27.3)
Missing	224 (0.6)	59 (0.2)	5 (0.01)	0 (0.0)	0 (0.0)	0 (0.0)	288 (0.1)
Child's characteristics							
Sex:							
Male	18 169 (52.0)	17 691 (51.9)	18 219 (51.5)	18 277 (51.7)	18 284 (51.9)	18 046 (51.5)	108 686 (51.7)
Female	16 797 (48.0)	16 412 (48.1)	17 154 (48.5)	17 058 (48.3)	16 978 (48.2)	16 979 (48.5)	101 378 (48.3)
Missing	11 (0.0)	13 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	24 (0.0)
Age, months:							
6-11	11 337 (32.4)	11 739 (34.4)	11 183 (31.6)	11 919 (33.7)	11 755 (33.3)	11 146 (31.8)	69 079 (32.9)
12-17	12 262 (35.1)	11 260 (33.0)	11 746 (33.2)	11 321 (32.0)	11 668 (33.1)	11 619 (33.2)	69 876 (33.3)
18-23	11 378 (32.5)	11 117 (32.6)	12 444 (35.2)	12 095 (34.2)	11 839 (33.6)	12 260 (35.0)	71 133 (33.9)
Preterm birth, ≤37 gestational weeks:							
No	33 412 (95.5)	32 686 (95.8)	34 007 (96.1)	33 831 (95.7)	33 729 (95.7)	33 428 (95.4)	201 093 (95.7)
Yes	1456 (4.2)	1375 (4.0)	1325 (3.8)	1476 (4.2)	1516 (4.3)	1553 (4.4)	8701 (4.1)
Missing	109 (0.3)	55 (0.2)	41 (0.1)	28 (0.1)	17 (0.1)	44 (0.1)	294 (0.1)
Birth weight:							
<2500 g	1313 (3.8)	1446 (4.2)	1450 (4.1)	1457 (4.1)	1583 (4.5)	1586 (4.5)	8835 (4.2)
2500-4000 g	31 998 (91.5)	31 009 (90.9)	32 117 (90.8)	32 167 (91.0)	31 823 (90.3)	31 693 (90.5)	190 807 (90.8)
>4000 g	1434 (4.1)	1514 (4.4)	1539 (4.4)	1559 (4.4)	1646 (4.7)	1736 (5.0)	9428 (4.5)
Missing	232 (0.7)	147 (0.4)	267 (0.8)	152 (0.4)	210 (0.6)	10 (0.0)	1018 (0.5)
Feeding and health							
Received the WHO recommended minimum acceptable diet in the past 24 h:							
No	18 404 (52.6)	16 843 (49.4)	16 702 (47.2)	16 807 (47.6)	17 053 (48.4)	21 058 (60.1)	106 867 (50.9)
Yes	9559 (27.3)	10 747 (31.5)	12 220 (34.6)	13 038 (37.0)	13 145 (37.3)	13 966 (39.9)	72 675 (34.6)
Missing	7014 (20.1)	6526 (19.1)	6451 (18.2)	5490 (15.5)	5064 (14.4)	1 (0.0)	30 546 (14.5)
Ever breastfed in the past 24 h:							
No	19 855 (56.8)	19 865 (58.2)	20 852 (59.0)	20 552 (58.2)	20 361 (57.7)	20 797 (59.4)	122 282 (58.2)
Yes	14 677 (42.0)	14 140 (41.5)	14 202 (40.2)	14 680 (41.6)	14 806 (42.0)	13 860 (39.6)	86 365 (41.1)
Missing	445 (1.3)	111 (0.3)	319 (0.9)	103 (0.3)	95 (0.3)	368 (1.1)	1441 (0.7)
Having acute respiratory infection in the past two weeks:							
No	30 173 (86.3)	30 082 (88.2)	31 890 (90.2)	32 161 (91.0)	32 721 (92.8)	33 078 (94.4)	190 105 (90.5)
Yes	4704 (13.5)	3978 (11.7)	3449 (9.8)	3139 (8.9)	2526 (7.2)	1921 (5.5)	19717 (9.4)
Missing	100 (0.3)	56 (0.2)	34 (0.1)	35 (0.1)	15 (0.0)	26 (0.1)	266 (0.1)
Having diarrhoea in the past two weeks:							
No	30 757 (87.9)	30 356 (89.0)	32 025 (90.5)	32 480 (91.9)	33 429 (94.8)	33 285 (95.0)	192 332 (91.6)
Yes	4134 (11.8)	3691 (10.8)	3302 (9.3)	2820 (8.0)	1814 (5.1)	1698 (4.9)	17459 (8.3)
Missing	86 (0.3)	69 (0.2)	46 (0.1)	35 (0.1)	19 (0.1)	42 (0.1)	297 (0.1)

Data are number (%). Data from 116 counties representing children aged 6-23 months living in China's poorest rural counties. County per capita GDP quarter was derived from the *China Statistical Yearbook (County-Level)* (2016-21) and the Bureau of Statistics of China at the county level and grouped into quarters. Monetary values were adjusted to the year 2016 using the annual *consumer price indexes at the province level in China. See supplementary text S3 for methods used to define the WHO minimum acceptable diet.*
GDPR=gross domestic product; WHO=World Health Organization.

In 2021, this percentage had decreased to 61.8%, with 18.4% having an education level of college and above.

Four main malnutrition forms were prevalent in 2016 (fig 2): anaemia (18.3%), stunting (7.5%), wasting (4.7%), and overweight (3.1%). However, the prevalence of any two coexisting malnutrition forms was low (fig 2), which seemed to occur randomly (supplementary table S3). All four malnutrition forms decreased from 2016 to 2021, with particularly fast reductions observed for anaemia and stunting. Anaemia decreased by over half, from 18.3% in 2016 to 8.9% in 2021. Stunting decreased by over a third, from 7.5% to 4.1%. Wasting (4.7% to 3.7%) and overweight (3.1% to 2.8%) also decreased, although at more modest rates. These findings were supported by Poisson regression analysis (table 2, table 3). After

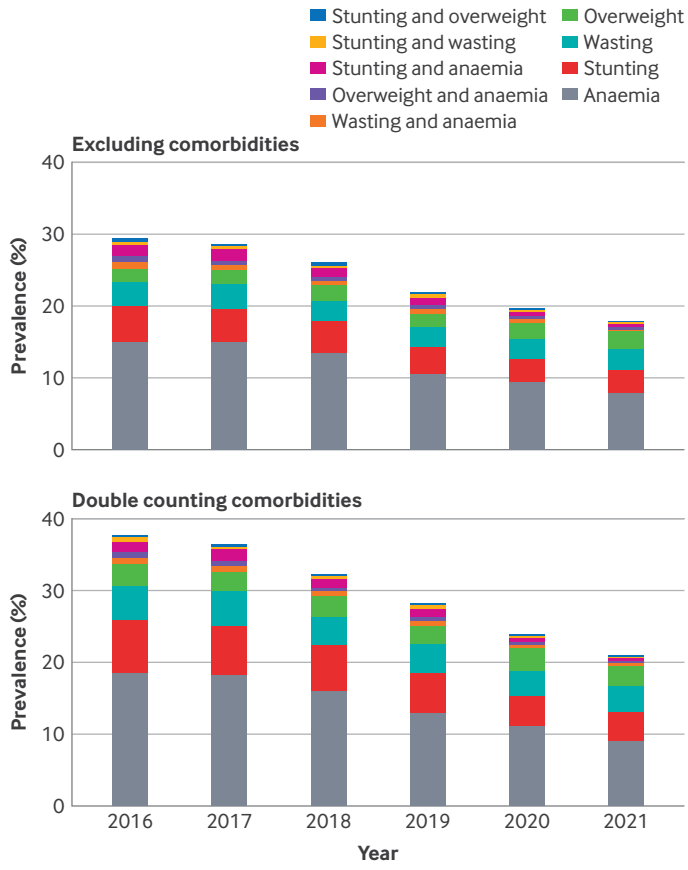

Fig 2 | Trends in all forms of malnutrition among children aged 6-23 months in China's poorest rural counties, 2016-21. Excluding comorbidities from each single form and double counting comorbidities in each single form are shown

adjusting for GDP group, mothers' education levels, children's age and sex, and all other covariates, the yearly trends reporting an annual reduction rate of 9.1% (1–rate ratios (95% CI 4.8% to 13.2%)) for anaemia and 10.4% (7.6% to 13.2%) for stunting.

Additional determinants for each of the four malnutrition forms are presented in table 2, table 3. Girls consistently reported lower risks than boys for each outcome. For example, the adjusted rate ratios of stunting comparing girls to boys was 0.65 (95% CI 0.61 to 0.69). Another determinant was children's age. As months of age increased, rates of stunting increased, while those of anaemia decreased. The prevalence of wasting was the highest for 12-17 months (rate ratio 1.17 (95% CI 1.09 to 1.26)), compared with the age of 6-11 months. Rates of overweight were roughly a third lower for 12-17 months (0.70 (0.64 to 0.77)) and 18-23 months (0.67 (0.60 to 0.74)) compared with 6-11 months. Figure 3 shows the measurements and prevalence by sex and age in months. For both girls and boys, anaemia prevalence decreased as age increased. Conversely, length-for-age z scores reduced almost linearly with age, leading to a rapidly increasing prevalence of stunting. Weight-for-length z scores decreased slightly until 16 months, with the prevalence of wasting and overweight plateauing after 1 year of age. Sex differences in wasting and overweight were small, but girls had less anaemia and stunting. Sex differences in anaemia decreased with age but was no different by 24 months. Length-for-age z scores decreased at similar paces for both sexes, with persistent sex differences in stunting in children aged 6-23 months.

In terms of socioeconomic characteristics, mothers' education levels generally had larger effects on malnutrition than GDP, except for the effects on anaemia (table 2, table 3). For example, for children whose mothers completed education only up to primary school level, the prevalence of stunting was 9.8% and of wasting was 6.2%. In comparison, for children whose mothers attained an education level of college or above, the rates were only 3.1% and 3.2%, respectively (absolute difference was 6.8% for stunting (relative difference, adjusted rate ratio 2.29 (95% CI 1.87 to 2.81)) and 3.0% for wasting (1.73 (1.40 to 2.13)), compared with primary school. However, the effects of GDP were small and largely attenuated by other factors (adjusted rate ratio for stunting was 1.02 (95% CI 0.81 to 1.28); for wasting was 1.26 (0.84 to 1.88)), comparing between the poorest quarter and the richest).

Figure 4 presents the yearly trends stratified by county GDP quarter and mothers' education for each malnutrition form. Although differences in stunting and wasting by county GDP quarter were small, they persisted across mothers' education levels. As indicated by the Poisson regression (table 4), the annual rates of anaemia reduction were similar across population subgroups. By contrast, stunting declined faster in the poorest counties and in children whose mothers had lower education levels compared to those in wealthier counties and with more educated mothers (supplementary table S4 for trends in wasting and overweight). Figure 5 presents the education related differences by age. Differences in anaemia, stunting, and wasting already existed at 6 months of age and changed only slightly between 6-23 months.

Discussion

Main findings

Using large scale survey data, this study provides a comprehensive analysis of the prevalence of malnutrition among children aged 6-23 months in China's poorest rural counties during 2016-21. We found little evidence for a double burden of malnutrition, but our data show that four forms of malnutrition (anaemia, stunting, wasting, and overweight) were present. The prevalence of each form reduced faster than the WHO global target. Changes occurred alongside a large scale reduction in poverty and substantial improvements in mothers' education levels. Gaps in growth among children in richer and poorer counties decreased, although differences in undernutrition related to educational level were common, with a larger effect on children whose mothers only completed education up to primary school level. As children's age increased, length-for-age z scores reduced faster than weight-for-length z

Table 2 | Determinants of stunting and wasting among children aged 6-23 months in China's poorest rural counties, 2016-21

Determinants	Stunting			Wasting		
	Prevalence of infants (%)	Crude, RR (95% CI)	Adjusted, RR (95% CI)	Prevalence of infants (%)	Crude, RR (95% CI)	Adjusted, RR (95% CI)
Annual trend	—	0.88 (0.84 to 0.92)	0.90 (0.87 to 0.92)	—	0.94 (0.89 to 1.00)	0.97 (0.92 to 1.03)
Socioeconomic characteristics						
County per capita GDP quarters:						
Richest (>$3909)	2095 (5.0)	1	1	1743 (3.7)	1	1
Richer ($3103-3909)	2245 (5.6)	1.12 (0.68 to 1.84)	1.02 (0.68 to 1.51)	1840 (4.1)	1.11 (0.81 to 1.53)	1.09 (0.82 to 1.46)
Poorer ($2352-3103)	2875 (5.5)	1.10 (0.70 to 1.73)	1.02 (0.73 to 1.43)	1898 (3.5)	0.94 (0.62 to 1.42)	0.91 (0.63 to 1.30)
Poorest (<$2352)	3370 (6.9)	1.36 (0.93 to 2.00)	1.02 (0.81 to 1.28)	2310 (5.1)	1.37 (0.91 to 2.05)	1.26 (0.84 to 1.88)
Mother's education:						
College or above	783 (3.1)	1	1	871 (3.2)	1	1
High school	1325 (4.1)	1.33 (1.15 to 1.53)	1.28 (1.09 to 1.51)	1182 (3.6)	1.14 (1.00 to 1.30)	1.09 (0.96 to 1.24)
Middle school	5569 (5.9)	1.93 (1.58 to 2.37)	1.59 (1.36 to 1.87)	3938 (4.0)	1.24 (1.07 to 1.45)	1.17 (1.00 to 1.38)
Up to primary school	2829 (9.8)	3.22 (2.65 to 3.91)	2.29 (1.87 to 2.81)	1772 (6.2)	1.94 (1.59 to 2.37)	1.73 (1.40 to 2.13)
Mother's ethnic group:						
Han	5606 (4.5)	1	1	4975 (3.8)	1	1
Other ethnic groups	4918 (9.2)	2.04 (1.67 to 2.49)	1.87 (1.59 to 2.20)	2803 (5.0)	1.31 (1.04 to 1.66)	1.24 (0.99 to 1.56)
Child's characteristics						
Sex:						
Male	6538 (6.9)	1	1	4461 (4.6)	1	1
Female	4047 (4.6)	0.67 (0.64 to 0.71)	0.65 (0.61 to 0.69)	3330 (3.6)	0.80 (0.74 to 0.86)	0.78 (0.73 to 0.84)
Age, months:						
6-11	2181 (3.4)	1	1	2718 (4.1)	1	1
12-17	3598 (6.1)	1.76 (1.59 to 1.95)	1.85 (1.66 to 2.07)	2786 (4.6)	1.13 (1.04 to 1.23)	1.17 (1.09 to 1.26)
18-23	4806 (7.8)	2.27 (2.02 to 2.56)	2.52 (2.17 to 2.94)	2287 (3.6)	0.89 (0.79 to 1.02)	1.02 (0.89 to 1.16)
Preterm birth, ≤37 gestational weeks:						
No	9623 (5.5)	1	1	7353 (4.0)	1	1
Yes	929 (13.1)	2.41 (2.21 to 2.62)	1.41 (1.18 to 1.69)	424 (5.8)	1.43 (1.27 to 1.61)	0.98 (0.78 to 1.22)
Birth weight:						
<2500 g	1236 (15.9)	1	1	612 (7.4)	1	1
2500-4000 g	9089 (5.5)	0.34 (0.30 to 0.39)	0.37 (0.30 to 0.46)	6983 (4.1)	0.55 (0.48 to 0.64)	0.51 (0.41 to 0.63)
>4000 g	173 (2.1)	0.13 (0.10 to 0.17)	0.16 (0.12 to 0.21)	153 (1.6)	0.21 (0.16 to 0.27)	0.21 (0.16 to 0.28)
Feeding and health						
Received the WHO recommended minimum acceptable diet in the past 24 h:						
No	5520 (5.6)	1	1	4347 (4.3)	1	1
Yes	2879 (4.7)	0.85 (0.74 to 0.96)	0.84 (0.77 to 0.92)	2290 (3.6)	0.83 (0.74 to 0.93)	0.90 (0.81 to 1.00)
Ever breastfed in the past 24 h:						
No	6225 (5.8)	1	1	4160 (3.9)	1	1
Yes	4301 (5.8)	1.00 (0.85 to 1.18)	1.41 (1.17 to 1.71)	3584 (4.6)	1.18 (1.01 to 1.38)	1.20 (1.01 to 1.43)
Having acute respiratory infection in the past two weeks:						
No	9502 (5.7)	1	1	6925 (4.0)	1	1
Yes	1065 (6.3)	1.10 (0.99 to 1.22)	1.06 (0.97 to 1.17)	853 (5.2)	1.32 (1.17 to 1.49)	1.25 (1.09 to 1.43)
Having diarrhoea in the past two weeks:						
No	9678 (5.8)	1	1	7056 (4.0)	1	1
Yes	889 (6.1)	1.06 (0.99 to 1.15)	1.01 (0.93 to 1.10)	716 (4.8)	1.19 (1.05 to 1.35)	1.09 (0.95 to 1.25)

Data from 116 counties representing children aged 6-23 months living in China's poorest rural counties. Adjusted RR was adjusted for years; County per capita GDP quarters; the mothers' education level and ethnicity; and the children's sex, age in months, preterm birth, birth weight, and feeding and health status. See supplementary text S3 for methods used to define the WHO minimum acceptable diet.
CI=confidence interval; GDP=gross domestic product; RR=rate ratio; WHO=World Health Organization.

scores. Boys had higher rates of undernutrition than girls. For all outcomes, differences related to sex and education were largest at 6 months of age.

Comparison with other studies

We appraised all combinations of concurrent malnutrition that were drawing substantial attention.[19 20] Our data suggest that, within China's poorest rural counties, the double burden of malnutrition may not be a priority. Previous studies from China have primarily focused on school aged children and adolescents, reporting declining rates of undernutrition but increasing overweight and obesity.[7-10] Our data corroborate the evidence that child undernutrition has decreased rapidly; with an annual rate of reduction exceeding 10%, stunting has decreased at a rate much faster than the global target of 3.9%.[21] In 2021, the prevalence of anaemia was lower than 13%, and the prevalence of stunting and wasting was also a low burden. Table S5 presents the estimated prevalence of malnutrition among the under 5s from selected countries, showing that the prevalence of each form of malnutrition in our population was near (or even lower than) that of the best-performing countries globally, such as Singapore, Japan, and Australia.[22] Since global data indicate that all four forms of child malnutrition are more severe during 6-23 months compared with 24-59 months,[23-25] our evidence suggests that China is making commendable progress towards sustainable development goal 2.2.

Table 3 | Determinants of anaemia and overweight among children aged 6-23 months in China's poorest rural counties, 2016-21

Determinants	Overweight			Anaemia		
	No of children with this malnutrition form (prevalence %)	Crude RR (95% CI)	Adjusted RR (95% CI)	No of children with this malnutrition form (prevalence, %)	Crude, RR (95% CI)	Adjusted, RR (95% CI)
Annual trend (2016-21)	—	0.99 (0.95 to 1.04)	1.00 (0.95 to 1.05)	—	0.86 (0.83 to 0.89)	0.90 (0.86 to 0.93)
Socioeconomic characteristics						
County per capita GDP quarters:						
Richest (USD >$3909)	1951 (2.4)	1	1	5528 (9.9)	1	1
Richer ($3103-3909)	2116 (2.5)	1.04 (0.73 to 1.49)	1.03 (0.74 to 1.42)	6129 (12.0)	1.22 (0.95 to 1.55)	1.17 (0.95 to 1.44)
Poorer ($2352-3103)	2337 (3.3)	1.34 (0.99 to 1.81)	1.26 (0.95 to 1.66)	7156 (12.5)	1.27 (0.96 to 1.67)	1.18 (0.92 to 1.52)
Poorest (<$2352)	2362 (3.2)	1.31 (0.96 to 1.78)	1.24 (0.91 to 1.68)	10 811 (20.9)	2.12 (1.59 to 2.82)	1.76 (1.33 to 2.32)
Mother's education:						
College or above	1183 (3.1)	1	1	3026 (9.7)	1	1
High school	1371 (2.7)	0.88 (0.79 to 0.99)	0.88 (0.78 to 1.00)	4659 (13.1)	1.36 (1.23 to 1.50)	1.20 (1.08 to 1.33)
Middle school	4793 (2.9)	0.95 (0.84 to 1.07)	0.92 (0.81 to 1.04)	16 454 (14.8)	1.53 (1.36 to 1.72)	1.24 (1.14 to 1.36)
Up to primary school	1388 (2.8)	0.93 (0.78 to 1.09)	0.92 (0.78 to 1.09)	5404 (16.2)	1.67 (1.44 to 1.95)	1.30 (1.11 to 1.53)
Mother's ethnic group:						
Han	6391 (2.9)	1	1	19 620 (13.0)	1	1
Other ethnic groups	2350 (2.8)	0.95 (0.79 to 1.13)	0.93 (0.79 to 1.09)	9943 (17.0)	1.32 (1.07 to 1.62)	1.20 (0.99 to 1.44)
Child's characteristics						
Sex:						
Male	4866 (3.2)	1	1	15 830 (14.5)	1	1
Female	3900 (2.5)	0.79 (0.73 to 0.86)	0.84 (0.77 to 0.91)	13 787 (13.7)	0.95 (0.92 to 0.98)	0.94 (0.90 to 0.97)
Age, months:						
6-11	3656 (4.1)	1	1	12 471 (18.1)	1	1
12-17	2741 (2.4)	0.59 (0.54 to 0.64)	0.70 (0.64 to 0.77)	10 643 (15.1)	0.84 (0.80 to 0.88)	0.92 (0.88 to 0.97)
18-23	2369 (2.1)	0.51 (0.46 to 0.55)	0.67 (0.60 to 0.74)	6510 (9.3)	0.52 (0.47 to 0.57)	0.59 (0.54 to 0.65)
Preterm birth, ≤37 gestational weeks:						
No	8434 (2.9)	1	1	28108 (14.0)	1	1
Yes	315 (2.4)	0.81 (0.69 to 0.96)	1.00 (0.84 to 1.19)	1460 (16.3)	1.17 (1.07 to 1.28)	1.11 (1.01 to 1.22)
Birth weight:						
<2500 g	241 (1.6)	1	1	1521 (17.0)	1	1
2500-4000 g	7637 (2.8)	1.71 (1.40 to 2.08)	1.72 (1.40 to 2.11)	26806 (14.0)	0.83 (0.76 to 0.90)	0.81 (0.75 to 0.88)
>4000 g	845 (6.4)	3.94 (3.16 to 4.91)	3.81 (3.00 to 4.83)	1110 (11.6)	0.68 (0.60 to 0.79)	0.67 (0.60 to 0.76)
Feeding and health						
Received the WHO recommended minimum acceptable diet in the past 24 h:						
No	5386 (3.6)	1	1	16 977 (15.6)	1	1
Yes	2442 (2.5)	0.68 (0.62 to 0.74)	0.83 (0.77 to 0.90)	8407 (11.8)	0.75 (0.67 to 0.84)	0.97 (0.89 to 1.07)
Ever breastfed in the past 24 h:						
No	3807 (2.1)	1	1	12771 (10.9)	1	1
Yes	4866 (4.2)	1.96 (1.79 to 2.14)	1.51 (1.37 to 1.66)	16705 (19.9)	1.82 (1.68 to 1.98)	1.70 (1.53 to 1.89)
Having acute respiratory infection in the past two weeks:						
No	8208 (3.0)	1	1	26334 (13.8)	1	1
Yes	545 (2.0)	0.68 (0.60 to 0.77)	0.70 (0.62 to 0.79)	3237 (16.4)	1.19 (1.12 to 1.27)	1.11 (1.05 to 1.17)
Having diarrhoea in the past two weeks:						
No	8138 (2.9)	1	1	26815 (13.9)	1	1
Yes	603 (2.6)	0.91 (0.79 to 1.04)	0.96 (0.84 to 1.09)	2760 (16.2)	1.17 (1.09 to 1.25)	1.03 (0.97 to 1.11)

Data from 116 counties representing children aged 6-23 months living in China's poorest rural counties. Adjusted RR was adjusted for years; county per capita GDP quarters; the mothers' education level and ethnicity; and the children's sex, age in months, preterm birth, birth weight, and feeding and health status. See supplementary text S3 for methods used to define the WHO minimum acceptable diet.
CI=confidence interval; GDP=Gross domestic product; RR=rate ratio; WHO=World Health Organization.

Importantly, the prevalence decreased during the study period and with the children's age, suggesting that overweight was well controlled for these infants and young children.

Our study showed several important findings on child malnutrition regarding age and sex. Firstly, length-for-age z scores decreased from 6 to 23 months, and did so faster than weight-for-length z scores. This finding concurs with the results of a recent cohort study conducted in 15 low and middle income countries,[3] which supports the global consensus that managing height and length is more important than managing weight.[26-28] Secondly, child anaemia is difficult to mitigate in low and middle income countries[21 29 30]; children aged 6-11 months have the highest prevalence of anaemia among the under 5s.[31-33] In our population, haemoglobin concentrations increased steadily in line with age; this decline in anaemia prevalence indicates an encouraging change. Thirdly, we observed poorer nutrition among boys than girls, which aligns with prior research.[34] Boys may be more susceptible to infectious diseases and have higher incidences of inflammation.[34] However, we found that in the poorest rural counties, sex differences in anaemia decreased as age increased, and no differences were noted at about 24 months. Although boys' linear growth lagged that of girls at 6 months of age, the sex differences did not increase from 6 to 23 months. In addition to providing

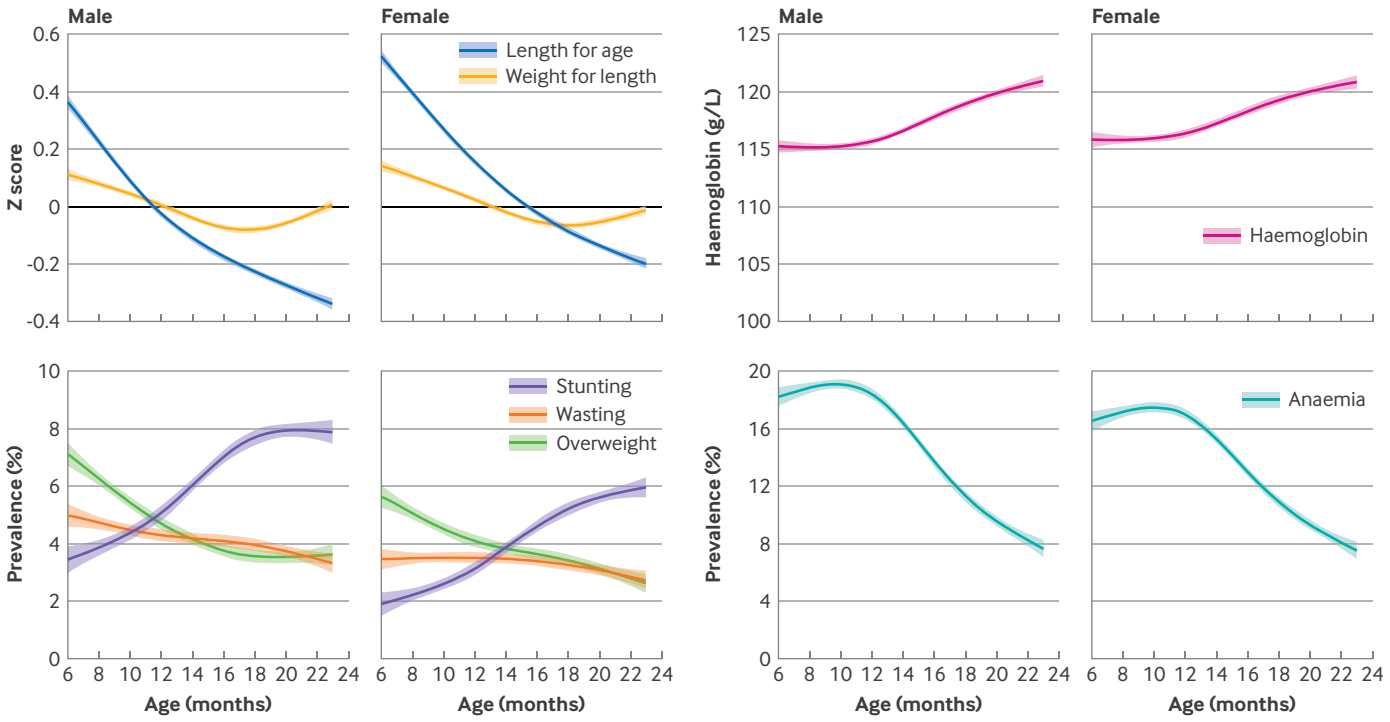

Fig 3 | Anthropometric measures and prevalence of malnutrition by sex and months of age among children aged 6-23 months in China's poorest rural counties, 2016-21. Length-for-age, weight-for-length z scores, and haemoglobin concentrations, and prevalence of anaemia, stunting, wasting, and overweight are shown

new data for sex differences in infant malnutrition under the age of 2 years, these data, taken together, suggest that the poorest rural communities could effectively manage undernutrition within 6-23 months.

Interpretations

We found that the large average annual rate of reduction in stunting and anaemia could not be explained by county GDP quarter, mothers' education and ethnic group, or the children's sex, age, feeding and health status, and preterm birth and weight at birth. According to global evidence, child undernutrition is determined by the complex interplay of social and economic factors, with high quality foods, improved hygiene, and adequate healthcare playing crucial roles.[35 36] Infant nutrition at 6-23 months is not only affected by feeding habits and health conditions, but mounting evidence suggests that maternal health and family conditions are also important.[3 17] The rapid increase in haemoglobin concentrations may be explained by the complementary food supplements programme: we found that 85% of the children in the study regularly took the supplements (data not shown). China's poverty reduction strategy is multisectoral. Despite food supplements, wider social determinants were targets of the so-called three guarantees, which focused on compulsory education for girls, securing jobs and safe housing that has improved hygiene and sanitation, and providing basic healthcare.[11-13] The progress in poverty reduction and improvement in mothers' education, along with the faster annual reduction rates in stunting in children living in poorer counties and less educated groups compared, support the success of China's approach to poverty reduction and nutrition interventions.

Focusing on China's poorest rural counties, this study adds valuable evidence to the discussion regarding the impact of geographical location versus individual socioeconomic status on achieving optimal nutrition for infants.[37 38] For stunting, wasting, and overweight, we found almost no differences by county GDP from 2016 to 2021, suggesting that subnational inequalities across geographical areas can successfully be addressed by large scale programmes. However, disparities remained for children whose mothers completed education up to primary school level. In rural areas, women's education was positively associated with their income and access to nutritious foods.[39] In these settings, women with an education at the middle school level (12-15 years old) or higher, compared with the least educated group, were more likely to have a secure job,[40] were better prepared for their pregnancy,[41] received higher quality antenatal care and post-partum support,[42 43] and were more likely to provide adequate complementary feeding to their children.[44] In our population, one in eight mothers completed education only up to primary school level in 2021, suggesting further efforts to make a change. Nevertheless, we found that the persistent inequalities related to education in child stunting and wasting already existed at 6 months of age and did not vary significantly between 6 and

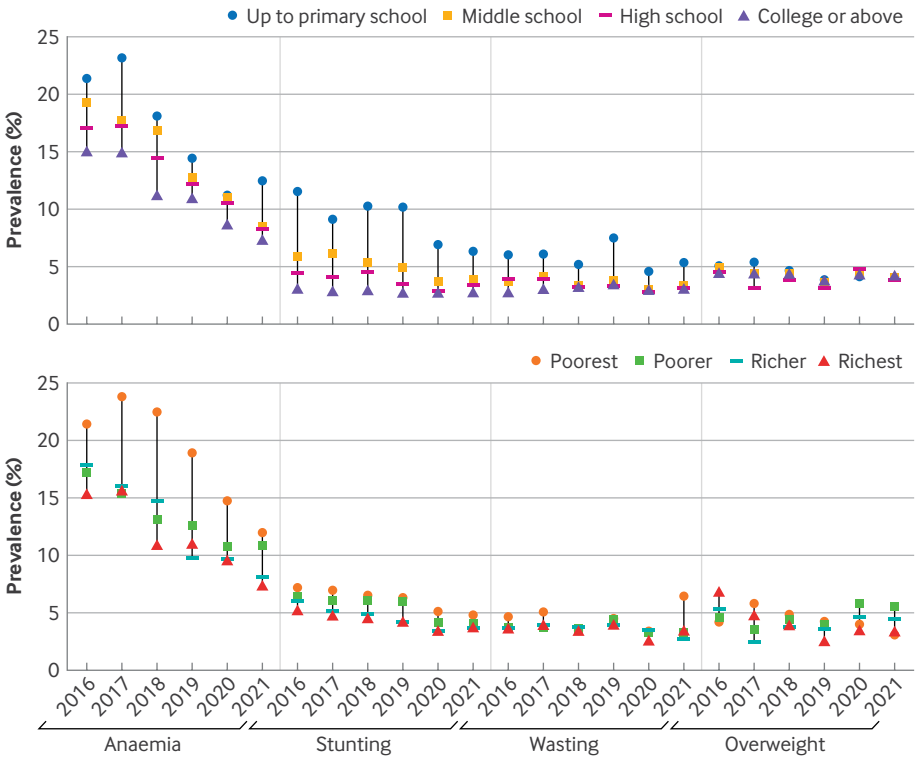

Fig 4 | Trends in prevalence of anaemia, stunting, wasting, and overweight among children aged 6-23 months in China's poorest rural counties, by mother's educational achievement and by gross domestic product (GDP) quarters, 2016-21. Trends by mother's educational achievement and by GDP quarters are shown

23 months. Future studies are needed to determine whether the so-called three guarantees and food supplements have helped to reduce inequalities related to education during complementary feeding. However, the largest disparities at 6 months of age suggest the importance of interventions during the breastfeeding period and earlier. In low and middle income countries, socioeconomic inequalities in child linear growth are not known to be affected more by maternal status or by interventions during periods of complementary feeding.[3] Our data indicate that child malnutrition policies and programmes

Table 4 | Average annual rate of reduction in anaemia and stunting by county GDP quartiles, mothers' education, child sex and months of age in China's poorest rural counties, 2016-21

Average annual rate of reduction	Stunting		Anaemia	
	Crude rate (95% CI)	Adjusted rate (95% CI)	Crude rate (95% CI)	Adjusted rate (95% CI)
Overall	12.09 (8.09 to 15.92)	10.44 (7.56 to 13.22)	14.77 (14.23 to 15.29)	9.11 (4.83 to 13.20)
By GDP quarters:				
Richest (USD >$3909)	7.33 (4.98 to 9.63)	5.37 (2.66 to 8.01)	14.21 (12.97 to 15.43)	11.79 (10.40 to 13.15)
Richer ($3103-3909)	10.67 (8.38 to 12.9)	8.79 (6.11 to 11.39)	15.63 (14.41 to 16.84)	14.60 (13.23 to 15.94)
Poorer ($2352-3103)	8.65 (6.68 to 10.59)	7.63 (5.43 to 9.78)	9.69 (8.46 to 10.90)	9.39 (8.07 to 10.70)
Poorest (<$2352)	7.15 (5.14 to 9.11)	12.95 (10.83 to 15.02)	8.52 (7.52 to 9.51)	10.45 (9.35 to 11.53)
By mother's education:				
College or above	1.96 (−2.33 to 6.06)	−0.60 (−5.74 to 4.28)	14.07 (12.33 to 15.78)	11.17 (9.15 to 13.14)
High school	7.27 (4.33 to 10.12)	6.85 (3.40 to 10.18)	13.72 (12.37 to 15.05)	10.00 (8.37 to 11.58)
Middle school	9.83 (8.47 to 11.18)	8.82 (7.18 to 10.43)	14.62 (13.90 to 15.33)	11.62 (10.77 to 12.46)
Up to primary school	9.62 (7.73 to 11.46)	10.15 (8.03 to 12.23)	13.33 (12.04 to 14.60)	11.21 (9.69 to 12.71)
By sex:				
Male	9.83 (8.58 to 11.06)	7.23 (5.73 to 8.71)	14.91 (14.19 to 15.63)	11.11 (10.15 to 12.06)
Female	12.68 (11.11 to 14.22)	9.88 (7.97 to 11.75)	14.59 (13.80 to 15.36)	11.23 (10.20 to 12.25)
By age:				
6-11	8.58 (6.30 to 10.80)	7.11 (4.61 to 9.53)	14.03 (13.21 to 14.83)	11.04 (10.00 to 12.06)
12-17	9.32 (7.63 to 10.97)	7.13 (5.15 to 9.07)	14.67 (13.79 to 15.54)	11.06 (9.89 to 12.22)
18-23	13.50 (12.09 to 14.89)	9.99 (8.17 to 11.78)	15.53 (14.38 to 16.67)	12.02 (10.36 to 13.64)

Data from 116 counties representing children aged 6-23 months living in China's poorest rural counties. The year was modelled as a linear variable to estimate the average annual rate of reduction (1−RR for the variable year. Adjusted RR was adjusted for years; GDP quarters; the mothers' education level and ethnicity; and the children's sex, age in months, preterm birth, birth weight, and feeding and health status.
CI=confidence interval; GDP=Gross domestic product; RR=rate ratio.

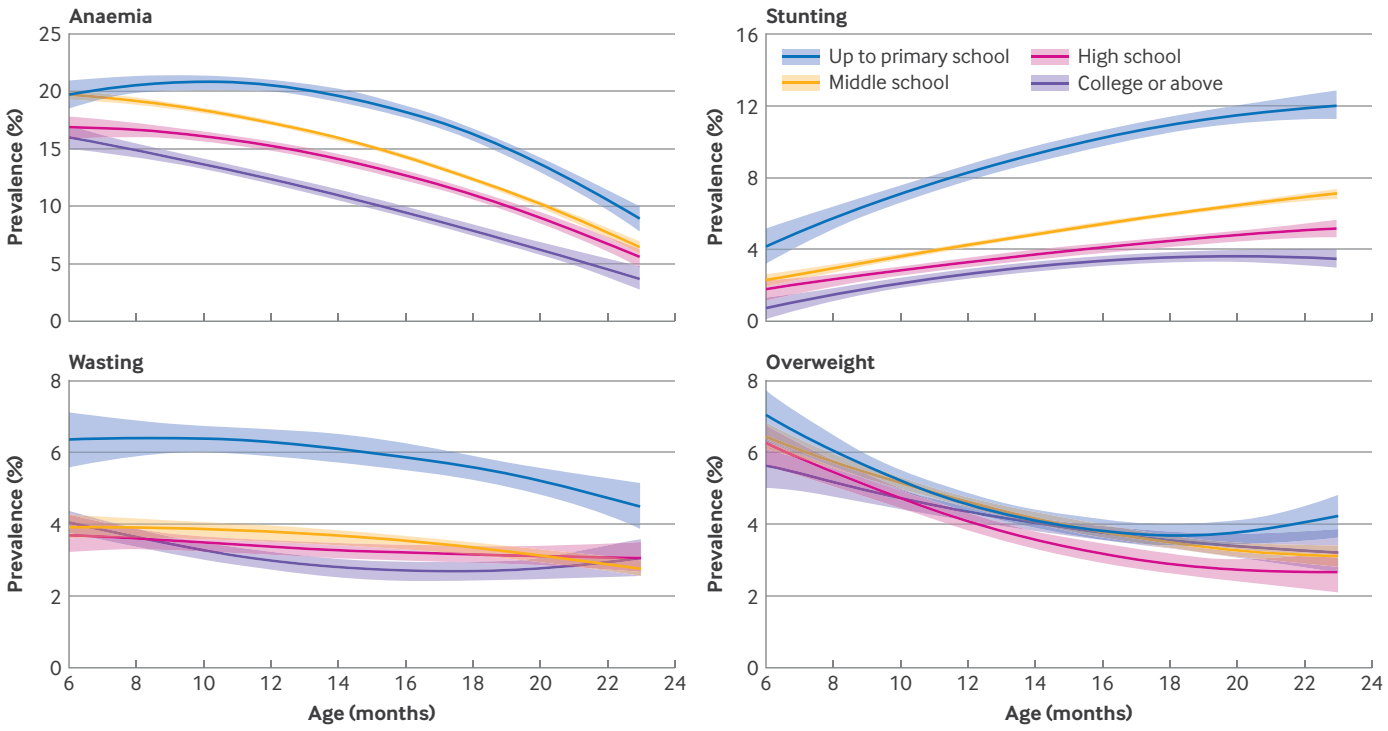

Fig 5 | Prevalence of anaemia, stunting, wasting, and overweight among children aged 6-23 months in China's poorest rural counties, by months of age and by mother's educational achievement, 2016-21

should place a greater focus on care for mothers, and preconception to post-partum care continuum should be prioritised.[3 45 46]

Limitations

Firstly, all surveys were cross sectional, and we were thus unable to track individual changes over time. Although we attempted to ensure consistency in data collection and processing methods, specific events or conditions unique to each year could have affected the comparability and interpretability of the results. Similarly, although we observed similar trends in child malnutrition by months of age, as in other studies,[3 47] causal inferences should be drawn with caution. Secondly, the survey did not collect data for household assets or income; therefore, we used county per capita GDP in the equity analysis. Future research is needed to gain a deeper understanding of income related inequalities at the individual level. Thirdly, the questionnaires did not adequately define breastfeeding and complementary feeding. Recall bias may have also undermined the quality of these data, particularly among the 25% of respondents who were fathers or grandparents. Fourthly, the complementary food supplements were distributed universally in all the counties in poverty when the survey was initiated. Due to only infants aged 6-23 months being eligible to receive government food supplements, whether the same success could be achieved in children aged 2-5 years, as endorsed in sustainable development goal 2.2, is unknown.

Conclusions

Using large scale data, we documented China's commendable progress in achieving sustainable development goal 2.2 among children aged 6-23 months, showing lessons for other countries seeking solutions for their poorest rural communities. With broad and integrated measures targeting the poorest regions, malnutrition (stunting, wasting, and anaemia) and overweight saw rapid declines, and geographical inequalities related to counties' economic development also decreased. Gaps mostly remained in education related socioeconomic inequities; children whose mothers only completed education up to primary school level had higher risks of faltering growth. Nevertheless, the inequalities related to education seemed to occur before 6 months of age, and these gaps did not widen by the age of 2 years. These findings suggest that greater attention should be directed towards mothers and interventions in the full maternal and child healthcare continuum.

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Ethical approval: The study was approved by the Ethics Committee of the Institute for Nutrition and Health, Chinese Centre for Disease Control and Prevention (No. 2014-001).

Data sharing: Individual participant data will not be made available publicly. Data that underlie the results reported in this article could be available, by researchers who provide a methodologically sound proposal, beginning nine months and ending 36 months following article publication. For further details on the data access policy and procedure, please contact the corresponding author at sunjing@ninh.chinacdc.cn.

Transparency: The lead authors (the manuscript's guarantors) affirm that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Dissemination to participants and related patient and public communities: The results will be shared with governments through research reports and policy briefs, and disseminated through social media, websites, televisions, and radios to raise public awareness.

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Web appendix: Supplementary appendices